AD-A115 529 ARMY ENGINEER DISTRICT ST LOUIS MO F/G 13/1
PERFORMANCE TEST: OKAW BLUFF BATHHOUSE SOLAR HOT WATER SYSTEM.(U)
JUN 82 M MERTENS, A H SWIFT

UNCLASSIFIED NL

1 OF 1
AD A115529

END
DATE
FILMED
7 82
DTIC

US Army Corps
of Engineers
St. Louis District

PERFORMANCE TEST: OKAW BLUFF BATHHOUSE SOLAR HOT WATER SYSTEM

M. MERTENS
A.H.P SWIFT

MECHANICAL ELECTRICAL SECTION
210 TUCKER BLVD., NORTH
ST. LOUIS, MO 63101

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. A115 529
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Performance Test: Okaw Bluff Bathhouse Solar Hot Water System	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. Mertens, A. H. P. Swift	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Mechanical-Electrical Section, St. Louis District, US Army Corps, 210 Tucker blvd., North, St. Louis Missouri 63101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE June 1982
	13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Solar Water Heating
Solar Acceptance Testing
Solar Economics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents data collected during testing at Okaw Bluff Bathhouse during July, 1980 and uses this data to evaluate the economic and energy conservation benefits of using solar hot water heating systems at recreational bath facilities.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

EXECUTIVE SUMMARY

The St. Louis District Energy Plan includes future installation of solar hot water systems at bath houses and future installation of solar heating systems at buildings at the lake projects. To determine the feasibility of installing solar systems we need data on actual costs and actual energy savings.

Cost data is readily available from solar systems already installed or being installed within the St. Louis District. No site specific energy savings information is readily available. Without accurate information on actual energy savings, the feasibility of future solar systems would be undefinable. Actual energy savings can only be determined by monitoring these solar systems during operation. The mobile solar performance testing system was developed by the St. Louis District for that purpose. The testing system is described in detail in this report.

As a result of this test we have concluded that the mobile solar performance testing system is capable of accurately recording actual energy savings for all liquid solar collector systems. This testing system also does an excellent job of evaluating system performance, determining system efficiencies and trouble shooting liquid solar collector systems. If additional information or consultation concerning the solar performance testing system is required please contact Mr. John Cullen or Mr. Mike Mertens in the Mechanical/Electrical Section of the Design Branch, St. Louis District Army Corps of Engineers.

As a result of this test we concluded that the solar hot water system at this facility had a 14 year payback. We will run similar tests on two other solar hot water systems in 1982 and use this data to determine the feasibility of solar hot water system retrofits at existing bathhouses. As a result of these tests we also concluded that all new bath houses in the St. Louis District should have solar hot water systems.

1.0 INTRODUCTION

This report describes a mobile, automated solar energy performance testing system developed by the Mechanical-Electrical Section of the St. Louis District, Corps of Engineers over the past year. It also presents solar performance data taken at Lake Shelbyville, Okaw Bluff bath house facility utilizing the test system. Although data were collected for only one week, several conclusions are drawn concerning the performance and operating cost savings of the solar hot water system at the facility. In addition, hot water consumption and demand profiles for the site are analyzed. The report also points out improvements planned for the testing system, which will provide longer term data collection and more complete system evaluation at other solar installations.

2.0 THE MOBILE SOLAR PERFORMANCE TESTING SYSTEM

With the installation of several solar facilities in the district, the need for evaluating the performance of these systems is evident. Actual system performance and energy savings can only be determined by monitoring these systems during operation for some time period.

Solar system performance measurements generally consist of measuring several energy flows. Usually these are insolation (solar flux), energy delivered by the collector loop, energy consumed by the load and back-up energy used. Due to the variability of these quantities, data taken over several months is necessary to fully characterize operation at a particular facility. The mobile solar performance testing system described herein was developed for this purpose.

The present testing system, designed to monitor liquid solar collector systems only, consists of the following components:

- One Spectran pyranometer to measure solar insolation.

- Dieterich standard annubars with differential pressure transducer for flow rate measurements.

- Tem-tex resistance temperature detector sensors hooked in a differential mode to measure temperature differences.

- Texas Instruments 960 microcomputer.

The system schematic is illustrated in Figure 1 and shows typical transducer placement for performance and load measurement. See also Reference 1 for further details concerning the testing system hardware.

The microcomputer samples insolation, flow rates, and temperature differences approximately 4000 times per hour. The program calculates average hourly and average daily energy flows for insolation, heat gain in the collector loop, hot water for domestic use and prints these values hourly. In addition, instantaneous values are printed based on hot water flow rates so that shower use patterns and valve sticking problems can be analyzed.

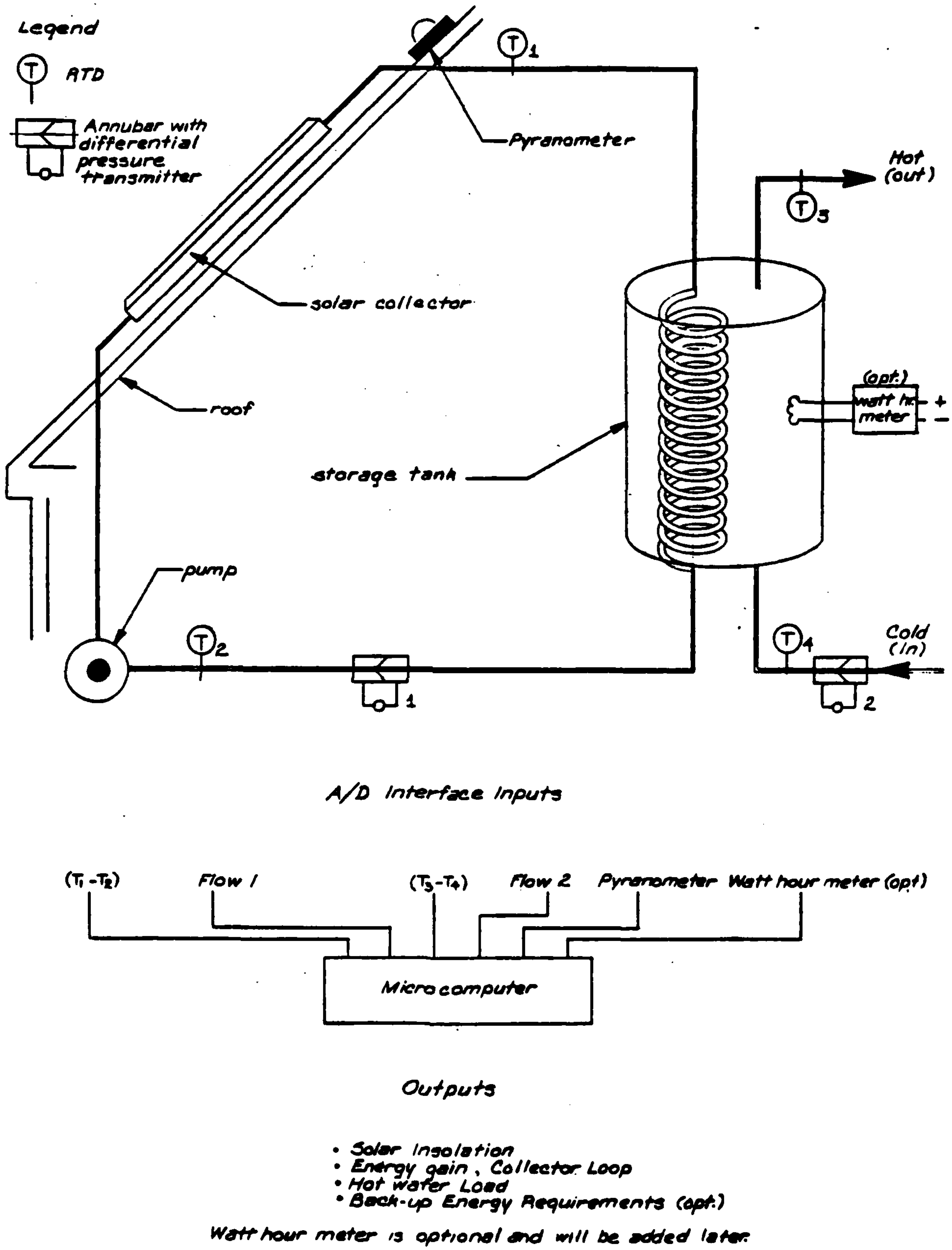

FIGURE 1. SOLAR TESTING SYSTEM SCHEMATIC

3.0 DATA AND ANALYSIS FOR SHELBYVILLE, OKAW BLUFF

The test system was installed in the Shelbyville, Okaw Bluff bath house facility to monitor the solar system performance and hot water load consumption at this site. Figure 2 illustrates the plumbing schematic and the placement of the monitoring system transducers for the test. The system consists of two Revere solar domestic hot water systems. Each system consists of three flat-plate solar collectors and one 80 gallon, stone lined, insulated storage tank with internal electric heater and solar loop heat exchanger. Total collector area is 112 ft^2. Other significant system specifications are shown on the drawing and are described more completely in Reference (2).

Data were collected during July 1980 for the system. Hot water usage data were collected for 8 days and solar system data for 4 days, as shown in TABLE 1.

TABLE 1
DATA COLLECTION TIMES

	Hot Water Use	Solar System Performance
Friday, July 4	X	
Saturday, July 12	X	
Sunday, July 13	X	
Monday, July 14	X	
Thursday, July 17	X	X
Friday, July 18	X	X
Saturday, July 19	X	X
Sunday, July 20	X	X

Based on these data, the following results are presented for Okaw Bluff.

(1) Hot water consumption data

a. TABLE 2 shows average hot water load profiles and flow rates for the facility.

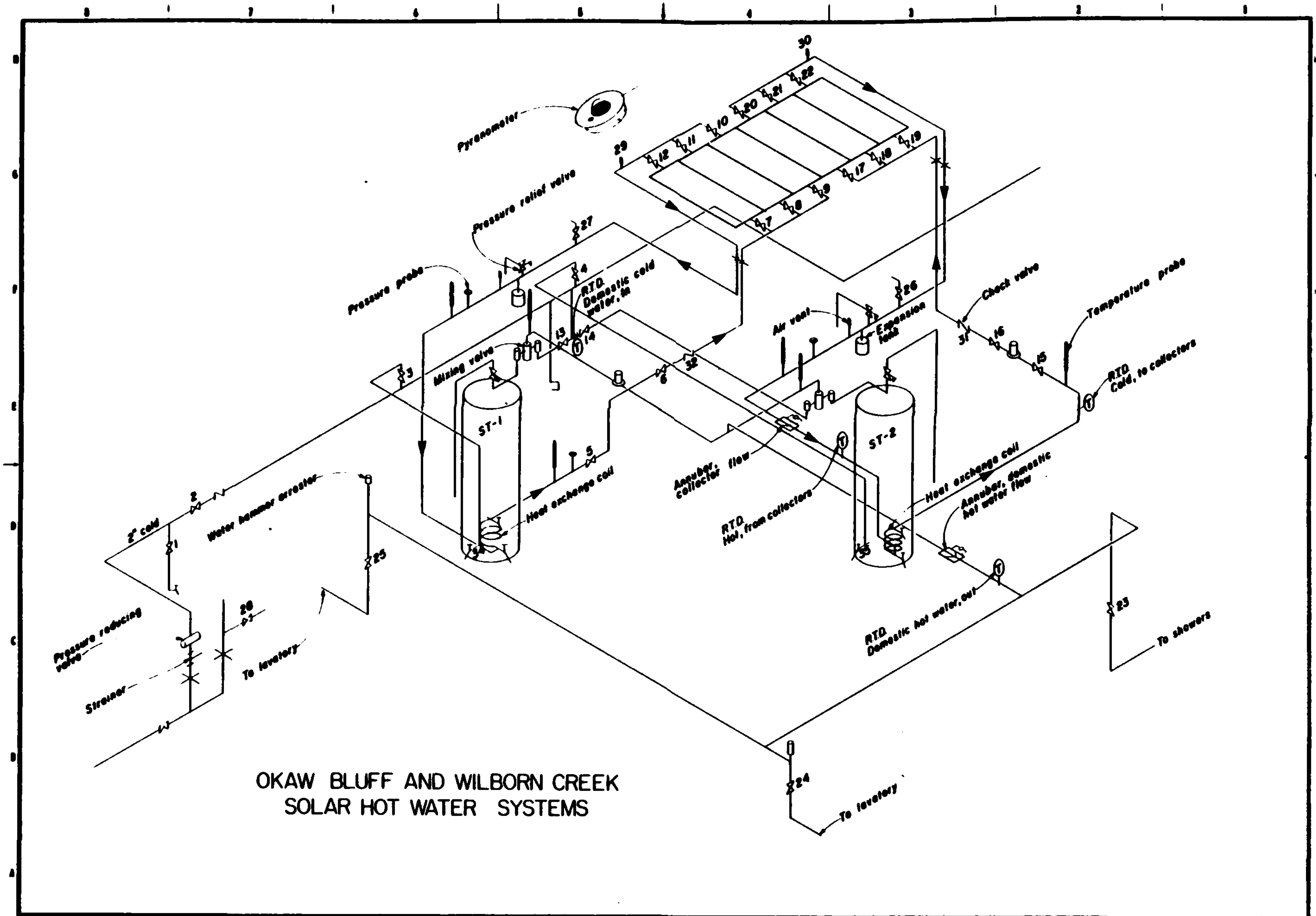
OKAW BLUFF AND WILBORN CREEK
SOLAR HOT WATER SYSTEMS
Pyranometer
Pressure relief valve
Pressure probe
R.T.D. Domestic cold water, in
Mixing valve
ST-1
ST-2
Heat exchange coil
Annuber, collector flow
R.T.D. Hot, from collectors
Air vent
Expansion tank
Check valve
Temperature probe
R.T.D. Cold, to collectors
Annuber, domestic hot water flow
R.T.D. Domestic hot water, out
2" cold
Water hammer arrestor
Pressure reducing valve
Strainer
To lavatory
To showers

FIGURE 2.

TABLE 2

HOT WATER LOAD PROFILES

Time (hour)	Week Day % Load	Week End % Load
0000 to 0900	0.0	0.0
1000	2.0	0.0
1100	2.0	1.2
1200	2.0	1.6
1300	2.0	7.4
1400	8.0	7.8
1500	11.0	13.0
1600	14.0	19.2
1700	16.0	12.4
1800	17.0	10.2
1900	9.0	8.2
2000	4.0	7.4
2100	12.0	7.8
2200	1.0	3.4
2300	0.0	1.2
Average Total Energy Consumption (Btu/day)	140,000	315,000
Estimated* gallons consumed (gal/day)	480	1,250

*(NOTE that these values are estimated based on average temperature differential and energy consumed data)

b. Peak hourly flow occurred on Sunday, July 20 at 1600 hours.

The peak hourly flow was 70,000 Btu/hr (381 gal/hr.)

c. A shower valve stuck open the night of Sunday, July 20. The valve was on from 2300 hours July 20 till 0900 hours, July 21.

Estimated waste: 200,000 Btu (60 kW hr)
670 gallons hot water.

d. The installed heating capacity is not sufficient to meet average weekend demand, resulting in colder than normal shower conditions. Figure 3, presented later, illustrates the extent of the problem for Saturday, July 19.

(2) Solar System Data

a. Average clear day total insolation was measured as 2411 Btu/ft^2 day, which correlates well with ASHRAE (3) clear day values of 2409 Btu/ft^2 for that location.

b. Data from one of the two solar loops indicate an average collector efficiency of 45% with values as high as 47% on high demand days (i.e. weekends) and as low as 43% on low demand days. These variations are explained by lower average tank temperatures and resulting higher collector efficiencies on high demand days.

c. Assuming both collector loops operate similarly, the collectors supply approximately 120,000 Btu/day. This is less than the average weekday consumption, indicating no overnight storage of solar heated water.

d. Assuming average collector efficiency of 45%, an 18% cloudiness factor, and an average daily load of 230,000 Btu/day the long-term solar fraction for July is 43.3%.

Therefore, average back-up power requirements should be near 1.6 kW. Electric meter readings taken on the 16th and 30th of July indicate an average power consumption of 1.7 kW, which correlates well with the predicted value. The difference is possibly explained by lighting and pumping requirements at the facility.

e. Typical weekend operation on a clear day is shown in Figure 3 for July 19, 1980. Note the large shower use peak, and the shower use temperature profile. Also, note that the collector efficiency is nearly constant at 45% throughout the day.

(3) Economic Data Based on System Performance.

Tables 3 and 4 present economic data based on these test results in order to determine the projected value of solar water heating systems at Corps bath facilities. Three systems are compared. The first is an oversized system which was the standard Corps design as existed several years ago at facilities with inexpensive electrical power. The extra capacity allowed for quick recovery and allowed for future facility expansion. The second design more closely resembles the installed solar design in size and capacity and should be used for comparison, since it is the system that would have been installed had the solar heating system not been used. The solar design is listed third.

Table 3 shows that one of the benefits of the solar design is that it uses a smaller capacity eletric heater, which reduces considerably the minimum monthly charge. This charge is based on installed transformer capacity and is applicable through the winter months when the facility is shut down. Also, as shown in Table 3, there is no demand charge at facilities below 50 KVA, although the energy charge is higher per KWhr. Due to the reduction in minimum charges and energy savings, the solar design provides significant savings. Table 4 shows a 2 year payback for the solar design, at current electric rates, as compared to the previous standard design, and 14 years as compared to a reduced capacity design, while saving approximately 43% in annual operating costs and energy consumption.

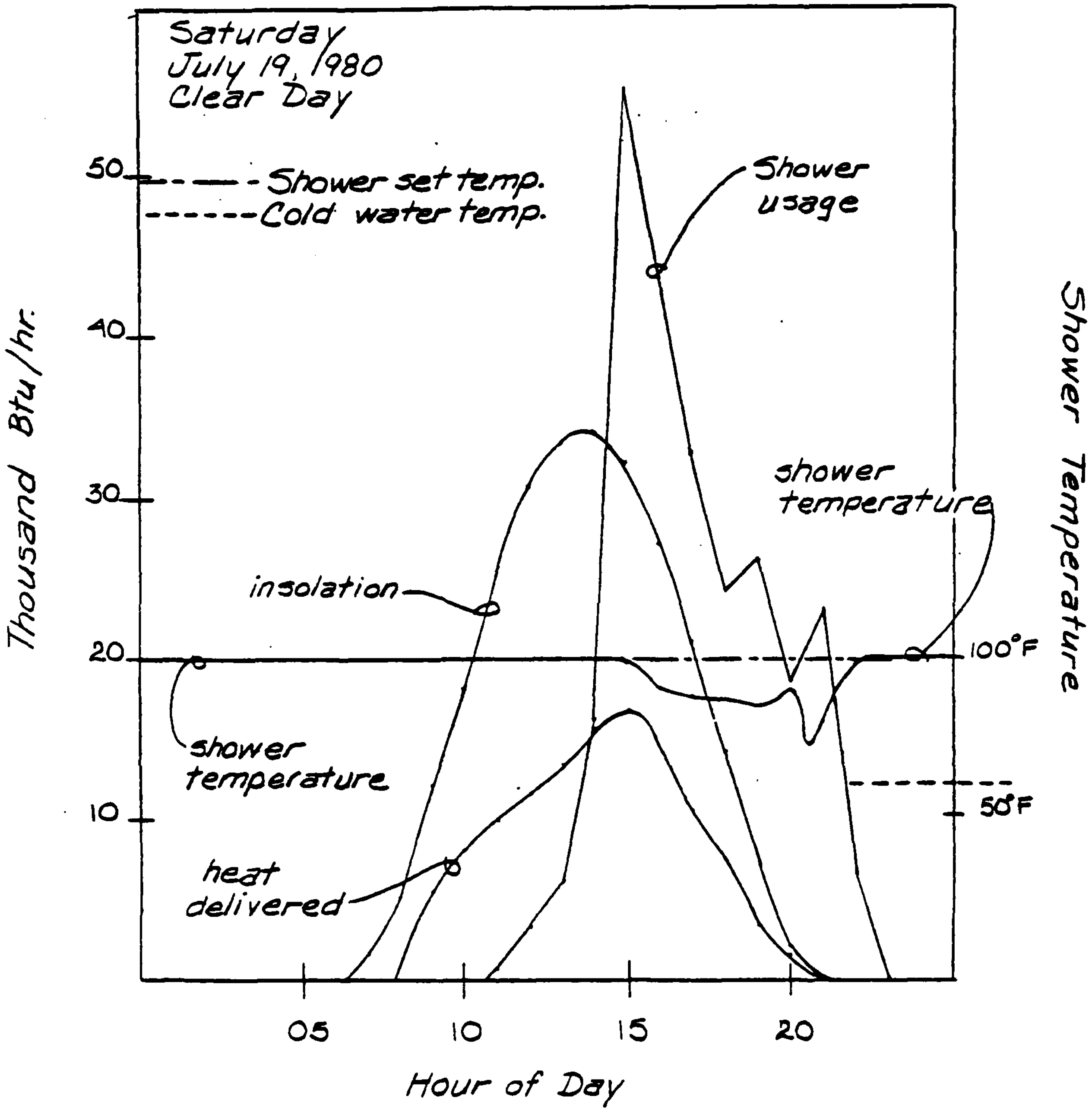

FIGURE 3. TYPICAL WEEKEND ENERGY FLOWS AND SHOWER TEMPERATURE

TABLE 3

SYSTEM COMPARISONS

System Design	Installed Capacity kW	Minimum Monthly Charge	Monthly Demand kW*	Monthly Demand Charge *	Monthly Energy kWhr *	Monthly Energy Charge *	Total Annual Operat. Cost
Previous Corp Standard All Electric 240 gal.	108	$143	20	$105	2,022	$102.62	$2039
Reduced Capacity All Electric 160 gal.	18	$17	18	0	2,022	$138.34	$811
Solar	9	$ 5	9	0	1,143	$84.72	$459

*Systems operates summer only, 5 months, May - September.

Analysis Assumes:

1. 230,000 Btu/day summer load.
2. September 1980, Coles-Moultrie Electric Co-op, Mattoon, Illinois electric rates.
3. Peak useage rate is 70,000 Btu/hr
4. Previous Corps Standard Design is oversized to allow for Facility Expansion.

TABLE 4
COST AND PAYBACK

	Installed Cost	Annual Operating Cost	Simple Payback for Solar
Previous Corps Standard All Electric	$3872	$2039	2 Years
Reduced Capacity All Electric	$2270	$ 811	14 years
Solar	$7260 ($65 per sq. ft.)	$ 459	-

4.0 IMPROVEMENTS FOR SOLAR TESTING SYSTEM

There are three listed improvements planned for the mobile solar performance testing system which should allow efficient, long term data collection for monitoring seasonal performance and operation of solar facilities. This will allow accurate accounting of cost and energy savings over an entire season rather than estimating performance and costs based on short-term performance measurements, as was done here. The system will also insure proper operation of newly installed systems over an entire season and record any degradation in performance. In addition, accurate load monitoring will identify problems and waste, (e.g. sticking shower valves) and allow for more efficient facility operation.

The first improvement will be replacement of the Texas Instrument 960 microcomputer by an Analog Devices, MACSYM II microcomputer. This will allow easier and faster programming and more flexible data compilation and output.

Second, flow rate measurements will be improved by adding specially calibrated annubars on all flow loops for more thorough system analysis.

Third, a digital watt-hour meter will provide both instantaneous and integrated power measurements to determine profiles for auxiliary energy utilization.

These improvements are expected to be completed in several months and the new system is planned to be installed in the solar heating system at the Cannon Visitors Center before the winter heating season.

5.0 BIBLIOGRAPHY

1. Solar Testing System Report, St. Louis District, U.S. Army Corps of Engineers, June 1980

2. Okaw Bluff and Wilborn Creek Solar Hot Water Systems, Operation and Maintenance Manual. St. Louis District, U.S. Army Corps of Engineers.

3. Jordan, R.C. and Liu, B.Y.H., "Applications of Solar Energy for Heating and Cooling of Buildings," American Society of Heating, Refrigerating and Air-Conditioning Engineers, GRP 170. 1977.

DATE

FILMED

7-8